

# Chemistry - basic lectures

A summer school student is required to attend all lectures in his or her primary discipline.

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### 1. Towards rational design of effective metal-based emitters and photosensibilizers

#### **Prof. Barbara Machura**

Transition metal complexes that exhibit enhanced absorption in the visible spectral region, high intersystem crossing (ISC) efficiency, and extended triplet excited-state lifetimes are highly promising candidates for use as photosensitizers. Such systems are particularly advantageous for applications in photocatalysis, photodynamic therapy (for generation of singlet oxygen or reactive oxygen species, ROS), and triplet-triplet annihilation upconversion (TTA UC) where low-energy light is converted into light of higher energy. Recent studies have shown that prolonging excited-state lifetimes in transition metal complexes can be achieved through population of triplet ligand-centered ( $^3\text{LC}$ ) states or formation of intraligand charge-transfer ( $^3\text{ILCT}$ ) states. In practice, this is accomplished by incorporating p-conjugated organic chromophores that possess long-lived non-emissive triplet states, as well as by introducing strong electron-donating organic substituents. This lecture will highlight correlations between ligand structural features and the resulting photophysical properties of transition metal complexes, with particular emphasis on their potential utility in aforementioned modern technologies.

## 2. Green Innovation Frontiers: Sustainable Resources and Technologies in Modern Chemistry

### **Jacek Nycz, PhD, DSc, Eng. Assoc. Prof.**

Sustainable chemistry is rapidly transforming how modern materials, chemicals, and energy carriers are produced. This lecture examines innovative green technologies that replace fossil-based routes with renewable resources, including biomass, agricultural residues, CO<sub>2</sub>, and lignocellulosic waste. Natural feedstocks enable the creation of valuable compounds, from bioplastics and biodiesel to vanillin and alkyl levulinates, while also supporting the biosynthesis of metal nanoparticles through clean, plant-based methods. Central attention is given to greener solvents—including supercritical CO<sub>2</sub>, deep eutectic solvents, and bio-derived alternatives—that significantly reduce the environmental footprint compared to traditional options like THF or toluene. We will discuss challenges such as resource stability, energy efficiency, and competition with the food sector, alongside emerging applications in UV-shielding lignin composites, nanostructured sensors, microwave-assisted synthesis, and hydrate-based desalination. The lecture highlights how these technologies contribute to shaping a circular, low-carbon future for the chemical engineering industry.

## 3. Surface Engineering in Energy Conversion

### **Mesude Zeliha Arkan, PhD, Emre Arkan, PhD**

The energetic performance of materials is strongly influenced by their surface properties and chemical composition. Key surface characteristics—roughness, functionalization, and charge distribution—govern interfacial interactions, charge-transfer efficiency, and energy dissipation, particularly in materials used for energy harvesting, storage, and conversion. Increased surface roughness can enlarge the contact area in triboelectric systems, enhancing charge generation, while specific functional groups modify the work function and electron affinity. At the compositional level, dopants, nanofillers, and tailored molecular structures can adjust the dielectric constant, electrical conductivity, and polarization behavior, all of which are critical for optimizing energy performance. This lecture will address these aspects through the following topics: Fundamentals of surface and interface properties; Surface treatment

methods; Techniques for measuring surface properties; Electrical properties influenced by surface engineering.

#### 4. Physical chemistry around us

##### **Prof. Marzena Dzida**

We'll learn why something warm has a higher temperature than something cold. Why we constantly have to clean our room and it's always a mess. We all know the phase transitions from our daily experiences of boiling water or watching an ice-cream melt on a hot day. Thanks to this, we begin to understand that there are different phases of matter and that, under the right conditions, matter can change phase, in which its properties change in a distinct and easily visible way. In this brief introduction, we consider the similarities and dissimilarities between phase transitions, and in particular how they are identified despite their sometimes exotic and different nature. We will analyze the phase diagram of water, carbon dioxide, tin. We will find and explain phase transitions around us and related effects. We will answer the following questions: How does a pressure cooker work? Why do we feel cold when we get out of the shower? Why are we ice skating and why can we throw snowballs? How can you get decaffeinated coffee? How is "Smoke" made in horror movies? We will describe the eruption of a geyser and much more. We will learn that physical chemistry is useful in managing companies, i.e. there will be a few words about systems thinking.

#### 5. Analytical Chemist as a Forensic Expert

##### **Prof. Grzegorz Zadora**

An analytical chemist serving as a forensic expert is responsible for the reliable examination of evidence using advanced instrumental analytical methods. Their role involves not only the identification and comparison of trace materials or chemical substances, but also the proper interpretation of results in the context of the forensic question, taking into account measurement uncertainty and methodological limitations. The expert's opinion becomes a key component in the decision-making process of law enforcement and the judicial system. During the lecture, students will become familiar with: the basic concepts and objectives of applying instrumental analytical methods in physicochemical forensic examinations; instrumental analytical

methods used in forensic laboratories for the analysis of evidential samples, with particular emphasis on the problem of trace evidence analysis, by a) scanning electron microscopy coupled with X-ray spectroscopy (SEM-EDX), b) X-ray fluorescence spectrometry (XRF,  $\mu$ -XRF), c) microspectrophotometry in the UV-VIS range (MSP), d) infrared spectroscopy (FTIR), e) Raman spectroscopy, f) chromatographic methods; the fundamental issues related to the interpretation of the evidential value of various types of data obtained in forensic laboratories, with particular emphasis on the likelihood ratio test.